Modeling the Effects of Climate Change and Sea-Level Rise on Groundwater Levels with Implications for Road Infrastructure in Coastal New Hampshire

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Climate Change Overview
Climate Change in the Northeast Temperature

Source: 2014 National Climate Assessment
Climate Change in the Northeast
Precipitation

Source: 2014 National Climate Assessment
Climate Change in the Northeast
Sea-Level Rise

Source: 2012 National Climate Assessment
Climate Change in the Northeast
Sea-Level Rise

Coastal NH – Winter storm 2/8/2016
Motivation for this study
Water is a major cause of damage to roads
The useful life of the pavement structure decreases with an increase in the percent of time the structure is saturated.

Source: Cedergren, 1988
High moisture content weakens the unbound layers
How does water get into pavement systems?

Through surface discontinuities

From edge

Capillary action

Vapor movements

Seepage from high ground

Rising water table

Water table
What does sea level have to do with groundwater?

Source: U.S. Geological Survey
Project Objectives

1. Create a NH Seacoast Transportation Climate Working Group
2. Identify roads that may be vulnerable to damage from rising groundwater
3. Determine the effects of climate change and sea-level rise on coastal groundwater levels
4. Conduct pavement performance evaluations
5. Demonstrate the value of adaptation through case study
Methods

• Update the USGS groundwater flow model of the Seacoast Region of NH (Mack, 2009) using MODFLOW-2005

• Identify areas where the groundwater is less than 10-feet deep using current and historical groundwater observations

• Simulate various sea-level rise scenarios to identify areas where groundwater is predicted to rise
Groundwater Model Construction
Political Map of Study Area
Groundwater Model

- Calculates the groundwater flow equation for many small areas, or cells, within the model domain

- Hydraulic properties of surficial and bedrock geology

- Groundwater recharge

- Streamflow

- Public and private water withdrawals and returns
GW model domain and boundary conditions
Model grid is 535 rows and 350 columns, each grid cell is 200’ x 200’
Observation wells and CSWs
Results – Groundwater Observations
**Depth to GW from observations (1960-2015)**

GW table is greater than or equal to 15-ft. below the ground surface.

GW table is very close to the ground surface

- Observation wells
Depth to GW in Portsmouth, NH
Depth to groundwater near the I-95/Rte. 16 Interchange in Portsmouth, NH
Depth to groundwater near Route 101 in Hampton—Evacuation Rte. From Hampton Beach
Preliminary Results – Groundwater Modeling
# Sea-level rise scenarios

<table>
<thead>
<tr>
<th>Time Period</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate low</td>
<td>0.6 ft.</td>
<td>1.6 ft.</td>
</tr>
<tr>
<td>Intermediate high</td>
<td>1.3 ft.</td>
<td>3.9 ft.</td>
</tr>
<tr>
<td>Highest</td>
<td>2.0 ft.</td>
<td>6.6 ft.</td>
</tr>
</tbody>
</table>

From: National Climate Assessment (Parris et al., 2012) using MSL as a reference
Surface water inundation with 6.6 feet of SLR

Groundwater rise with 6.6 feet of SLR
Observed depth to gw and simulated depth to gw with 6.6 feet of sea-level rise
Transect of the off-ramp from I-95 through the Portsmouth Circle
The groundwater is predicted to rise approximately 4-5 feet along this section of road.
Rise in GW with 6.6 feet of SLR

Why doesn’t the GW rise as much here?
Increase in GW level is reduced in the proximity of streams, but . . .

- Streamflow will increase.
- The freshwater/salt water interface may move further inland.
Increase in GW levels with 6.6-feet of SLR
What factors make coastal road infrastructure vulnerable to changes in climate?

- Proximity to the ocean
- Locations where groundwater is near the ground surface and where groundwater is projected to rise
- Inadequate stream crossings now or in the future
- Subgrade soil types that weaken with increasing moisture content
Conclusions

➢ Groundwater modeling is an effective tool for investigating spatially variable hydrologic changes resulting from climate change.

➢ Rising groundwater and changing flow patterns will have important consequences for the structural integrity of infrastructure, water supply and water quality, stream base flow, and the health of natural ecosystems.

➢ Adaptation strategies must consider potential damage from rising groundwater in addition to surface water impacts.
Future research

- Investigate how groundwater recharge and levels are influenced by changing precipitation patterns and temperature due to climate change

- Model pavement performance with changing groundwater levels, temperatures, and precipitation

- Conduct case studies for adaptation planning

- Use groundwater modeling to investigate the potential for seawater intrusion and the degradation of groundwater quality with sea-level rise in the town of Newmarket, NH
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Thank you

Questions?

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